

## FCRI Evaluation of Orifice Meter Validation System

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### 1. ABSTRACT

In 2016, FCRI undertook testing of a commercially available system (“Prognosis”) designed to validate DP meter performance, by assuring the end user of correct DP meter operation or alerting the end user to the presence of various meter system malfunctions. Tests were performed on a 4” orifice meter with air flow in the FCRI closed loop test facility.

The comprehensive test program started with a correctly operating orifice meter to show the baseline normal response of the system to a fully serviceable meter, i.e. the common response in the field. Then, common meter problems were deliberately induced by the FCRI laboratory. These orifice meter malfunction tests include:

- Incorrect inlet diameter
- Incorrect orifice diameter
- Orifice beta changed but not updated
- Drifting transmitter or scaling error
- Leaking DP transmitter manifold
- Orifice plate installed backwards
- Worn orifice edge
- Partially blocked orifice
- Blocked flow straightener (i.e., inlet swirl/disturbance)

The “Prognosis” response to these FCRI orifice meter malfunction tests will be presented, including an assessment of the capabilities of the system to assure good meter performance, and the guidance it gives regarding the possible source/s of the malfunction. These FCRI test results add to industry’s growing understanding about the capabilities of this orifice meter validation and diagnostic system.

### 2. SUMMARY

Eximp International conducted Orifice Assembly Tests, based on PROGNOSIS and CALIBRATION, in FLUID CONTROL RESEARCH INSTITUTE(FCRI), PALAKKAD. FCRI- a Premier research institute in INDIA which is equipped with a full-fledged NAB accredited laboratories for the calibration of flow meters in water, oil, and air media.

The test were conducted on 4” Nominal bored Orifice having Model number 415RFSC and Serial No. was EX4959/01. The tests were conducted with preference of 42.18mm throat diameter and 103.91mm pipe diameter.

Reference standard used for the ORIFICE ASSEMBLY was a Turbine meter /ISO 9951 with Calibration medium

as Air under FCRI Procedure WP/ AHP/ CC/ 04 at the Air flow laboratory.

### 3. INTRODUCTION

#### Ambient conditions

996±1 mbar      28±1 °C      63±5 %

#### Calibration method

The Calibration is done using Air as per FCRI procedure WP/AHP/CC/04. The reference used is part of the Closed Loop Test Facility and consists of Turbine meter.

The test meter is mounted in series at downstream of the reference meter.

#### Data

The data are given in Table 1. The Prognosis software data are given in Tables 4 to 14.

#### Results

The calibration results are given in Table 2. And prognosis test screenshots and photographs of test setup are given in Fig 1 to 27. The conclusion report is given in Table 16.

#### Uncertainty

The uncertainty in Calibration is estimated as per NABL 141 ‘Guidelines for Estimation and Expression of Uncertainty in Measurement’ and FCRI procedure FCRI\AHP\UE\01. Accredited uncertainty of the reference system is 0.3% as per NABL Accreditation Certificate No.: C-0026, Valid Until 21/08/2018. The uncertainty budget is given in Table 3.

#### Traceability

All instruments, meters used are traceable to National standards (NPL, New Delhi) and their calibration is current.

#### FCRI Reference

Major equipment used and selected from Equipment List: HP/QLTY/15, Rev 14, 04-08-2016 is listed below.

Equipment Name	File No.	Calibration due date
Turbine Meter	FCRI/AFL/HP/F06	16-Mar-17
Multifunction Pressure Indicator	FCRI/AFL/HP/P04	16-Aug-17
Differential pressure transmitter	FCRI/AFL/HP/P25	16-Aug-17
Temperature indicators	FCRI/AFL/HP/T01,T10	17-Feb-16, 15-Dec-16
Universal counter	FCRI/AFL/HP/C01	16-Mar-17
Dew point transmitter	FCRI/AFL/HP/H04	16-Mar-17

Table 1  
Data of calibration

Sl. No.	Reference Meter				Item under calibration					
	Pressure $P_r$ bar a	Temperature $T_r$ °C	Pulses $F_r$ -	Time $t_r$ s	Pressure $P_i$ bar a	Temperature $T_i$ °C	Differential pressure $\Delta P$ mbar	Traditional Differential Pressure $\Delta P_t$ mbar	Recovery Differential Pressure $\Delta P_r$ mbar	Permanent Pressure Loss $\Delta P_{PEL}$ mbar
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
1	16.1862	24.93	92456	60	16.0637	26.00	228.07	228.80	84.84	144.29
2	16.1792	25.02	92260	60	16.0571	25.96	226.73	227.45	84.23	143.49
3	16.1661	24.99	76187	60	16.0877	26.10	153.41	153.57	57.16	96.93
4	16.1426	24.95	76194	60	16.0621	26.10	153.40	153.42	57.11	96.82
5	16.1313	24.94	76159	60	16.0520	26.10	153.03	153.43	57.26	96.71
6	16.1234	24.95	76153	60	16.0456	26.10	152.90	153.41	57.27	96.62
7	16.1163	25.00	76126	60	16.0373	26.10	152.63	153.00	57.04	96.47
8	16.1340	25.04	62514	60	16.0839	26.20	102.90	102.79	38.67	64.81
9	16.1367	25.13	44098	60	16.1180	26.40	50.66	50.43	19.28	31.94
10	16.1253	25.09	44092	60	16.1055	26.60	50.68	50.51	19.32	31.89
11	16.1251	25.08	62548	60	16.0762	26.30	102.81	102.75	38.65	64.84
12	16.1351	24.97	91994	60	16.0118	26.20	224.83	225.75	83.71	142.27

Compressed Air Relative humidity, % 0

Table 2  
Result of Calibration

Sl. No.	Nominal pressure bar a	Mass flowrate kg/s	Actual flow rate $q_a$ m <sup>3</sup> /h	Reynolds number ReD -	Coefficient of discharge $C_t$ -
[1]	[2]	[3]	[4]	[5]	[6]
1	16	1.8252	349.84	1.21E+06	0.6088
2		1.8200	348.93	1.21E+06	0.6089
3		1.5019	287.53	9.99E+05	0.6096
4		1.5000	287.63	9.98E+05	0.6094
5		1.4983	287.49	9.97E+05	0.6096
6		1.4974	287.43	9.96E+05	0.6096
7		1.4960	287.30	9.95E+05	0.6097
8		1.2297	235.55	8.18E+05	0.6091
9		0.8673	165.90	5.76E+05	0.6112
10		0.8667	166.03	5.76E+05	0.6111
11		1.2295	235.71	8.17E+05	0.6095
12		1.8101	348.31	1.20E+06	0.6093

Mean C = 0.6097

(575737 < ReD < 1214468)

Expanded uncertainty, U (k=2): 0.34% Reading

Table 3  
Uncertainty budget

Source of uncertainty	Estimate		Limits		Probability distribution		Standard uncertainty		Sensitivity coefficient	Uncertainty contribution	Degree of freedom	$u_i^4 / \sum u_i^4$
$X_i$	$x_i$		$\pm \Delta x_i$		n	Divisor	$u(x_i)$	$c_i$	$u_i(y)$	$\nu$		
Air temperature, $T_1$	26.00	°C	3.00E-01	°C	Type B, Normal	2	1.50E-01	°C	1.98E+02	2.97E+01	$\infty$	0
		°C	3.61E-03	°C	Type A	1	3.61E-03	°C	1.98E+02	7.14E-01	0	-
Best fit line			7.00E+00	Pa	Type B, Rectangular	1.732	4.04E+00	Pa	1.00E+00	4.04E+00	$\infty$	0
Relative humidity, $R_h$	0	%	5.70E-01	%	Type B, Normal	2	2.85E-01	%	3.36E+01	9.57E+00	$\infty$	0
Vapour pressure, $P_1$ (100%)	3357.473	Pa	5.99E+01	Pa	Type B, Normal	2	2.99E+01	Pa	0.00E+00	0.00E+00	$\infty$	0
<b>Vapour pressure, <math>P_1</math> (%<math>R_h</math>)</b>	<b>0.00</b>	<b>Pa</b>	<b>Combined standard uncertainty, <math>u_b</math></b>				<b>9.569E+00</b>	<b>Pa</b>				
Molecular weight of dry air, $M_{da}$	28.959	kg/kmol	0.00E+00	kg/kmol	Type B, Rectangular	1.732	0.00E+00	kg/kmol	0.00E+00	0.00E+00	$\infty$	0
Molecular weight of water, $M_w$	18.016	kg/kmol	0.00E+00	kg/kmol	Type B, Rectangular	1.732	0.00E+00	kg/kmol	0.00E+00	0.00E+00	$\infty$	0
Vapour pressure, $P_v$	0.000	Pa	1.91E+01	Pa	Type B, Normal	2	9.57E+00	Pa	6.81E-06	6.52E-05	$\infty$	0
Compressibility air pressure, $P_1$	16.0637	bar a	2.00E-02	%	Type B, Normal	2	1.61E+02	Pa	0.00E+00	0.00E+00	$\infty$	0
			1.40E-04	bar	Type A	1	1.40E+01	Pa	0.00E+00	0.00E+00	0	-
<b>Molecular weight, <math>M_a</math></b>	<b>28.95900</b>		<b>Combined standard uncertainty, <math>u_b</math></b>				<b>6.519E-05</b>	<b>-</b>				
Vapour pressure, $P_v$	0.00	Pa	1.91E+01	Pa	Type B, Normal	2	9.57E+00	kg/kmol	2.77E-09	2.65E-08	$\infty$	0
Pressure at reference meter, $P_1$	16.1862	bar a	2.00E-02	%	Type B, Normal	2	1.62E+02	Pa	0.00E+00	0.00E+00	$\infty$	0
		bar a	3.73E-04	bar	Type A	1	3.73E+01	Pa	0.00E+00	0.00E+00	0	-
Compressibility of dry air, $Z_{dt}$	0.995518	-	1.00E-01	%	Type B, Rectangular	1.732	5.75E-04	Pa	1.00E+00	5.75E-04	$\infty$	0
<b>Compressibility of wet air, <math>Z_t</math></b>	<b>0.99552</b>		<b>Combined standard uncertainty, <math>u_b</math></b>				<b>5.748E-04</b>	<b>-</b>				
Vapour pressure, $P_v$	0.00	Pa	1.91E+01	Pa	Type B, Normal	2	9.57E+00	kg/kmol	2.65E-09	2.54E-08	$\infty$	0
Pressure at test meter, $P_1$	16.0637	bar a	2.00E-02	%	Type B, Normal	2	1.61E+02	Pa	0.00E+00	0.00E+00	$\infty$	0
		bar a	1.40E-04	bar	Type A	1	1.40E+01	Pa	0.00E+00	0.00E+00	0	-
Compressibility of dry air, $Z_{dt}$	0.995736	-	1.00E-01	%	Type B, Rectangular	1.732	5.75E-04	Pa	1.00E+00	5.75E-04	$\infty$	0
<b>Compressibility of wet air, <math>Z_t</math></b>	<b>0.99574</b>		<b>Combined standard uncertainty, <math>u_b</math></b>				<b>5.749E-04</b>	<b>-</b>				
Beta ratio, $\beta$	0.59840	-	0.00E+00	-	Type B, Normal	2	0.00E+00	-	-	-	$\infty$	0
Differential pressure at test meter, $\Delta P_t$	22.807	kPa	6.50E-03	%	Type B, Normal	2	7.41E+01	Pa	-	-	$\infty$	0
			1.50E-03	kPa	Type A	1	1.50E-01	Pa	-	-	0	-
Pressure at test meter, $P_t$	16.0637	bar a	2.00E-02	%	Type B, Normal	2	1.61E+02	Pa	-	-	$\infty$	0
		bar a	1.40E-04	bar	Type A	1	1.40E+01	Pa	-	-	0	-
Isentropic exponent, $\gamma$	1.40	-	1.46E-04	-	Type B, Rectangular	1.732	1.18E-06	-	-	-	$\infty$	0
<b>Expansion factor, <math>Y_t</math></b>	<b>0.99594</b>		<b>Combined standard uncertainty, <math>u_b</math></b>				<b>4.969E-02</b>	<b>-</b>				
Pulses, $F_t$	92456	pulse	1.00E+00	pulse	Type B, Rectangular	1.732	5.77E-01	pulse	6.58E-06	3.80E-06	$\infty$	0
Pressure at reference meter, $P_1$	16.1862	bar a	2.00E-02	%	Type B, Normal	2	1.62E+02	Pa	3.76E-07	6.09E-05	$\infty$	0
		bar a	3.73E-04	%	Type A	1	3.73E+01	Pa	3.76E-07	1.40E-05	0	-
K-factor, $K_t$	16038.8	pulse/m <sup>3</sup>	3.00E-01	%	Type B, Normal	2	2.41E+01	pulse/m <sup>3</sup>	-3.80E-05	-9.13E-04	$\infty$	0
Time, $t_t$	60.0	s	1.43E-04	s	Type B, Normal	2	7.15E-05	s	-1.01E-02	-7.25E-07	$\infty$	0
Compressibility factor, $Z_t$	0.99552	-	5.75E-04	-	Type B, Normal	2	2.87E-04	-	-6.12E-01	-1.76E-04	$\infty$	0
Air temperature at reference meter, $T_1$	24.93	°C	3.00E-01	°C	Type B, Normal	2	1.50E-01	K	-2.04E-03	-3.06E-04	$\infty$	0
		°C	4.31E-03	°C	Type A	1	4.31E-03	K	-2.04E-03	-8.80E-06	0	-
Beta ratio, $\beta$	0.59840	-	0.00E+00	-	Type B, Normal	2	0.00E+00	-	-2.99E-01	0.00E+00	$\infty$	0
Air temperature at test meter, $T_t$	26.00	°C	3.00E-01	°C	Type B, Normal	2	1.50E-01	K	1.02E-03	1.53E-04	$\infty$	0
		°C	3.61E-03	°C	Type A	1	3.61E-03	K	1.02E-03	3.67E-06	0	-
Compressibility factor, $Z_t$	0.99574	-	1.15E-03	-	Type B, Normal	2	5.75E-04	-	3.06E-01	1.76E-04	$\infty$	0
Molecular weight, $M_a$	28.9590	kg/kmol	1.30E-04	kg/kmol	Type B, Normal	2	6.52E-05	kg/kmol	1.05E-02	6.85E-07	$\infty$	0
Pressure at test meter, $P_t$	16.0637	bar a	2.00E-02	%	Type B, Normal	2	1.61E+02	Pa	-1.89E-07	-3.04E-05	$\infty$	0
		bar a	1.40E-04	bar	Type A	1	1.40E+01	Pa	-1.89E-07	-2.65E-06	0	-
Throat diameter, $d_t$	0.062180	m	0.00E+00	m	Type B, Normal	2	0.00E+00	m	-1.96E+01	0.00E+00	$\infty$	0
Expansion factor, $Y_t$	0.99594	-	4.97E-02	%	Type B, Normal	2	2.47E-04	-	-6.11E-01	-1.51E-04	$\infty$	0
Differential pressure at test meter, $\Delta P_t$	22.807	kPa	6.50E-03	%	Type B, Normal	2	7.41E-01	Pa	-1.33E-05	-9.89E-06	$\infty$	0
		kPa	1.50E-03	kPa	Type A	1	1.50E+00	Pa	-1.33E-05	-2.00E-05	0	-
Universal gas constant, R	8314.4	J/kmol K	1.00E-02	%	Type B, Rectangular	1.7321	4.80E-01	J/kmol K	-3.66E-05	-1.76E-05	$\infty$	0
<b>Coefficient of discharge, <math>C_t</math></b>	<b>0.6098</b>	<b>-</b>	<b>Combined standard uncertainty, <math>u_B</math></b>				<b>1.02E-03</b>	<b>-</b>				
<b>Meter coefficient of discharge, <math>C_t</math></b>	<b>0.6097</b>			<b>Type A standard uncertainty, <math>u_A</math></b>			<b>2.23E-04</b>	<b>-</b>	<b>1.00E+00</b>	<b>2.23E-04</b>	<b>11</b>	<b>2.23E-16</b>
				<b>Combined standard Type A uncertainty, <math>u_C</math></b>			<b>2.23E-04</b>	<b>-</b>				
				<b>Combined standard uncertainty, <math>u_C</math></b>			<b>1.04E-03</b>	<b>-</b>				
				<b>Effective degree of freedom, <math>n</math></b>			<b>5342.2</b>	<b>-</b>				
				<b>Coverage factor, <math>k</math></b>			<b>2.0</b>	<b>-</b>				
		<b>Expanded uncertainty, U</b>			<b>2.1E-03</b>	<b>-</b>	<b>0.34 % reading</b>					

$$C_t = \left( \frac{F_t \times (P_t \times 10^5)}{K_t \times t_t \times Z_t \times (273.15 + T_t)} \right) \times \frac{4 \times \sqrt{1 - \beta^4} \times \sqrt{T_t} + 273.15 \times \sqrt{Z_t} \times \sqrt{M_a}}{\sqrt{2 \times \pi \times \sqrt{P_t \times 10^5} \times d_t^3 \times Y_t \times \sqrt{\Delta P_t} \times 100 \times \sqrt{R}}}$$

## Prognosis baseline data

Below is an example of Prognosis during the initial orifice calibration by FCRI. FCRI performed a calibration on the orifice meter in order to determine average Discharge Coefficient over a range of flows using the reference Turbine meter.

Prognosis calculates three flow rate predictions using three different Differential Pressure measurements and calculations based on industry standards (in this case ISO 5167 2003) and well understood physical principles.

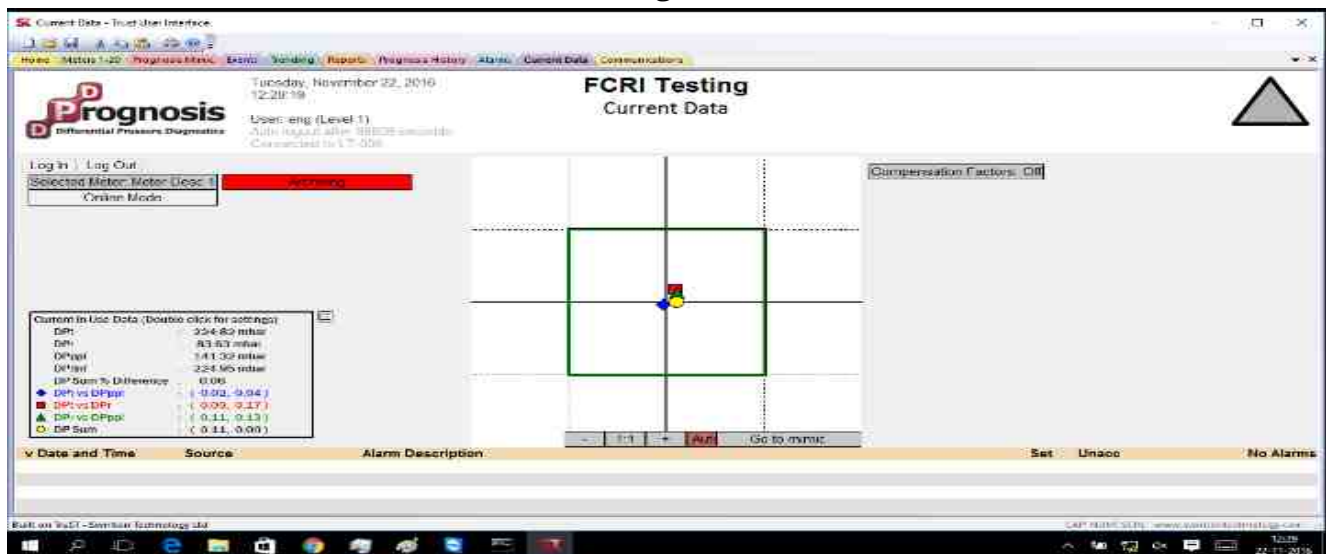
Fig. 1



Fig. 2



Fig. 3



During the initial FCRI calibration, prior to tests, the Prognosis results confirmed good Orifice meter performance.

The meter geometry was as follows:

Pipe Inlet Diameter = 103.91 mm

Orifice Diameter = 62.18 mm

Beta Ratio ( $\beta$ ) = 0.6

For each test presented in this report, the Orifice flow rate prediction error is either calculated directly where possible (this is possible in cases of incorrect meter geometry and error in Meter DP, presented in Part A) or estimated by comparing reported orifice meter flow rate to reference flow rate.

### Prognosis test data (Part A)

**i) Input the meter inlet diameter to flow computer too high**

**Objective** – Determine whether the DUT detects that the Orifice meter inlet diameter is entered too high.

**Criteria** – DUT should react in accordance with the manufacturers’ specifications.

**A) Observed Measured Readings**

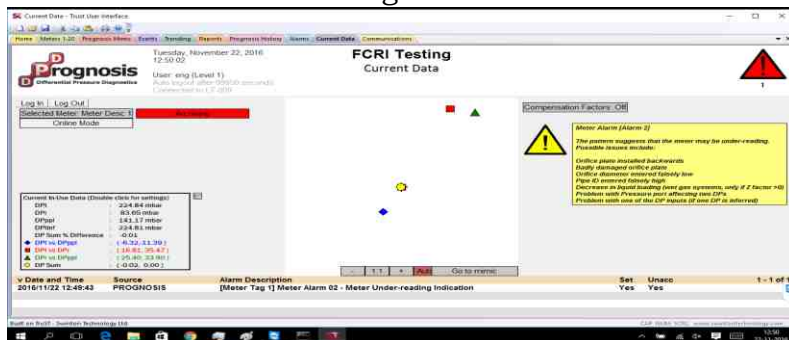
- a) Original pipe diameter, D= 103.91 mm
- b) Incorrectly entered pipe diameter, D = 130.91 mm
- c) Corresponding flow rate prediction error = - 4.64%.

Table 4

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter					Meter under test			Traditional	Recovery	Permanent
Pressure	Temperature	Pulse	Time	Actual flow rate	Pressure	Temperature	Differential Pressure	Differential Pressure	Differential Pressure	Pressure Loss
Pr bar a	Tr °C	Fr -	tr s	qa m <sup>3</sup> /h	Pt bar a	Tt °C	ΔP mbar	ΔPt mbar	ΔPr mbar	ΔPPPL mbar
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
16.1238	24.94	92018	60	348.33	15.9999	26.10	224.84	225.85	83.70	142.29

**B) Results displayed on the Prognosis Screen**

Fig. 4



**C) Conclusion:**

Prognosis can detect and guide the user to address if the in-use inlet diameter of orifice is high.

**ii) Input the meter inlet diameter to flow computer too low**

**Objective** – Determine whether the DUT detects that the Orifice meter inlet diameter is entered too low.

**Criteria** – DUT should react in accordance with the manufacturers' specifications.

- a) Original pipe diameter, D= 103.91 mm
- b) Incorrectly entered pipe diameter, D = 100 mm
- c) Corresponding flow rate prediction error = +1.3%

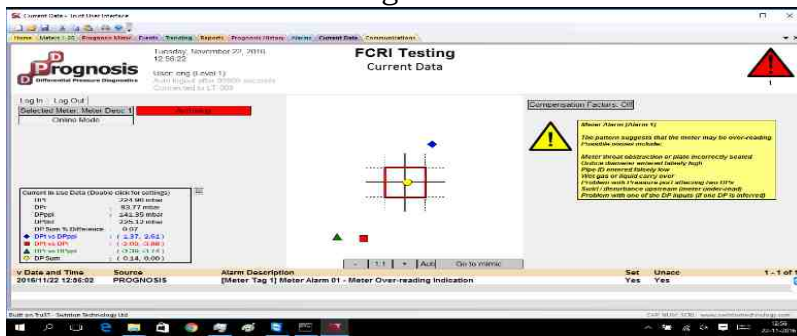
**A) Observed Measured Readings**

Table 5

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter					Meter under test			Traditional	Recovery	Permanent
Pressure	Temperature	Pulse	Time	Actual flow rate	Pressure	Temperature	Differential Pressure	Differential Pressure	Differential Pressure	Pressure Loss
Pr bar a	Tr °C	Fr -	tr s	qa m <sup>3</sup> /h	Pt bar a	Tt °C	ΔP mbar	ΔPt mbar	ΔPr mbar	ΔPPPL mbar
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
16.1135	24.93	92075	60	348.53	15.9908	26.10	225.23	225.88	83.82	142.39

**B] Results displayed on the Prognosis Screen**

Fig. 5



**C] Conclusion:**

Prognosis can detect and guide the user to address if the in use inlet diameter of orifice is low.

**iii) Input the meter orifice diameter to flow computer too high**

**Objective** – Determine whether the DUT detects that the Orifice meter diameter is entered too high.

**Criteria** – DUT should react in accordance with the manufacturers' specifications.

- a) Original orifice diameter, d= 62.18 mm
- b) Incorrectly entered Orifice diameter, d = 63.18 mm
- c) Corresponding flow rate prediction error = +3.77%

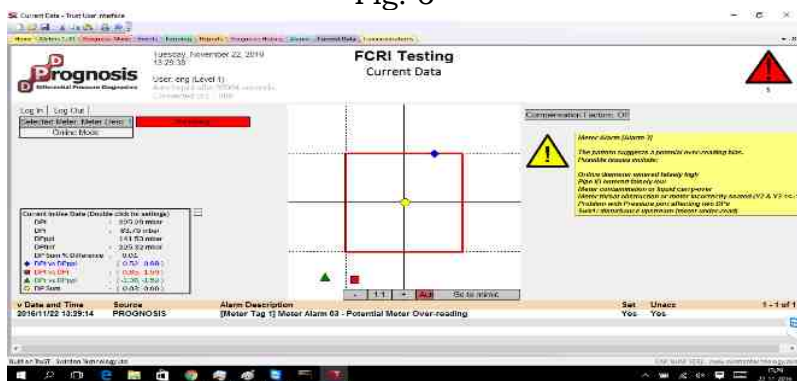
**A] Observed Measured Readings**

Table 6

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter				Meter under test				Traditional Differential Pressure ΔPt mbar	Recovery Differential Pressure ΔPr mbar	Permanent Pressure Loss ΔPPPL mbar
Pressure Pr bar a	Temperature Tr °C	Pulse Fr -	Time tr s	Actual flow rate qa m <sup>3</sup> /h	Pressure Pt bar a	Temperature Tt °C	Differential Pressure ΔP mbar			
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
16.1051	24.91	92152	60	349.01	15.9806	26.20	225.20	226.23	84.02	142.46

**B] Results displayed on the Prognosis Screen**

Fig. 6



**C] Conclusion:**

Prognosis can detect and guide the user to address if the in-use orifice diameter is high.

**iv) Input the meter orifice diameter to flow computer too low**

**Objective** – Determine whether the DUT detects that the Orifice meter diameter is entered too low.

**Criteria** – DUT should react in accordance with the manufacturers' specifications.

- a) Original orifice diameter, d= 62.18 mm
- b) Incorrectly entered Orifice diameter, d = 61.18 mm
- c) Corresponding flow rate prediction error = -3.66%

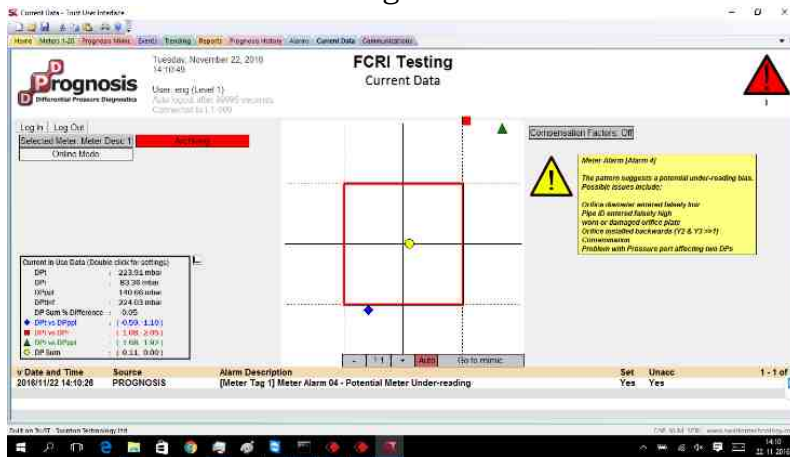
**A) Observed Measured Readings**

Table 7

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter				Meter under test				Traditional	Recovery	Permanent
Pressure	Temperature	Pulse	Time	Actual flow rate	Pressure	Temperature	Differential Pressure	Differential Pressure	Differential Pressure	Pressure Loss
Pr	Tr	Fr	tr	qa	Pt	Tt	ΔP	ΔPt	ΔPr	ΔPPPL
bar a	°C	-	s	m³/h	bar a	°C	mbar	mbar	mbar	mbar
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
16.1351	24.97	91994	60	348.31	16.0118	26.20	224.83	225.75	83.71	142.27

**B) Results displayed on the Prognosis Screen**

Fig.7



**C) Conclusion:**

Prognosis can detect and guide the user to address if the in-use orifice diameter is low.

**v) Faulty DP reading (e.g., drifting transmitter, scaling error or badly calibrated transmitter)**

**Objective** – Determine whether the DUT detects a faulty DP reading.

**Criteria** – DUT should react in accordance with the manufacturers' specifications.

**Method** - Traditional DP mA scaling incorrectly adjusted (via internal push-buttons) from 4-20mA to 3.8-20mA to simulate a drifting or badly calibrated transmitter

- a) Traditional DP Reading in error by 4.65 mbar (-2.1%)
- b) Corresponding flow rate prediction error = -1.04%

**A) Observed Measured Readings**

Table 8

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter				Meter under test				Traditional	Recovery	Permanent
Pressure	Temperature	Pulse	Time	Actual flow rate	Pressure	Temperature	Differential Pressure	Differential Pressure	Differential Pressure	Pressure Loss
Pr	Tr	Fr	tr	qa	Pt	Tt	ΔP	ΔPt	ΔPr	ΔPPPL
bar a	°C	-	s	m³/h	bar a	°C	mbar	mbar	mbar	mbar
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
15.9547	25.04	91999	60	348.51	15.8318	26.40	222.30	223.32	82.82	136.03

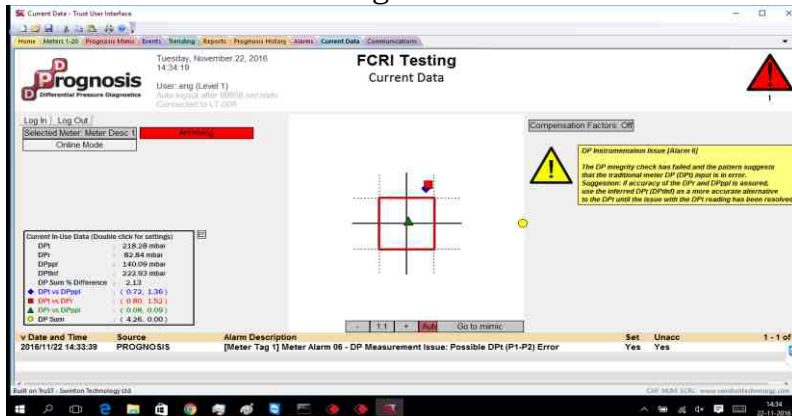
**B) Traditional DP mA scaling adjusted slightly (via internal push-buttons) to simulate a drifting or badly calibrated transmitter”**

Fig.8



**C) Results displayed on the Prognosis Screen**

Fig. 9



**D) Conclusion:**

Prognosis can detect and guide the user to address if there is an error in DP reading cause by (for example) incorrect scaling, faulty, drifting or badly calibrated transmitter.

**vi) Faulty DP readings (Leaking Manifold)**

**Objective** – Determine whether the DUT detects a faulty DP reading.

**Criteria** – DUT should react in accordance with the manufacturers' specifications.

**Method** – Open Equalisation valve anticlockwise (approx. 30 degrees)

Approx. flow rate prediction error: -1.9%

**A) Observed Measured Readings**

Table 9

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter					Meter under test			Traditional	Recovery	Permanent
Pressure	Temperature	Pulse	Time	Actual flow rate	Pressure	Temperature	Differential Pressure	Differential Pressure	Differential Pressure	Pressure Loss
Pr bar a	Tr °C	Fr -	tr s	qa m <sup>3</sup> /h	Pt bar a	Tt °C	ΔP mbar	ΔPt mbar	ΔPr mbar	ΔPPPL mbar
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
15.9547	25.04	91999	60	348.51	15.8318	26.40	214.46	215.66	80.72	138.65

**B) Leaking Manifold/Impulse tubing.**

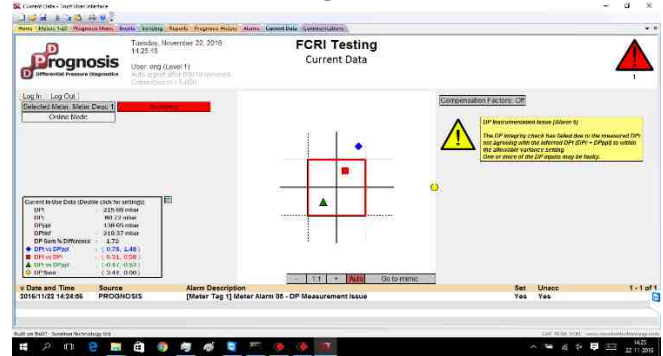
**Criteria** - Opening Equalization anticlockwise: 30 degrees (approx.)

**C] Results displayed on the Prognosis Screen**

Fig 10



Fig. 11



**D] Conclusion:**

Prognosis can detect and guide the user to address if there is an error in DP reading cause by (for example) a leaking manifold or equalization valve not fully closed.

**Prognosis test data (Part B)**

**i) Orifice plate installed backward**

**Objective** – Determine whether the DUT detects that the Orifice meter inserted is backward.

**Criteria** – DUT should react in accordance with the manufacturers' specifications.

**A] Observed Measured Readings**

Table 10

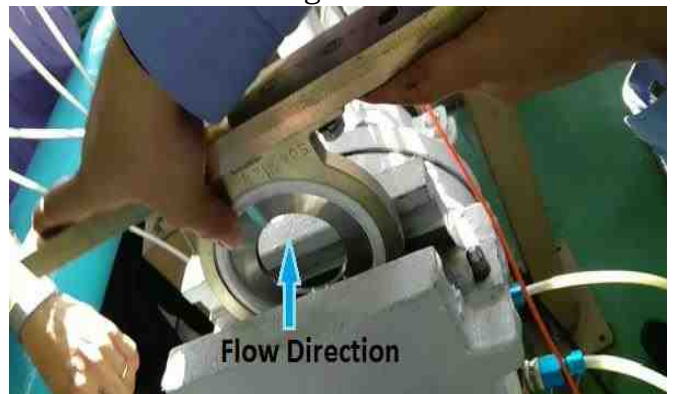
FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter				Meter under test				Traditional Differential Pressure $\Delta Pt$ mbar	Recovery Differential Pressure $\Delta Pr$ mbar	Permanent Pressure Loss $\Delta PPPL$ mbar
Pressure Pr bar a	Temperature Tr °C	Pulse Fr -	Time tr s	Actual flow rate qa m <sup>3</sup> /h	Pressure Pt bar a	Temperature Tt °C	Differential Pressure $\Delta P$ mbar			
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
16.1139	24.98	91982	60	348.64	15.9897	26.50	152.61	152.32	64.66	88.16

**B] Reversed orifice plate (Id No. FE-01)**

Fig. 12

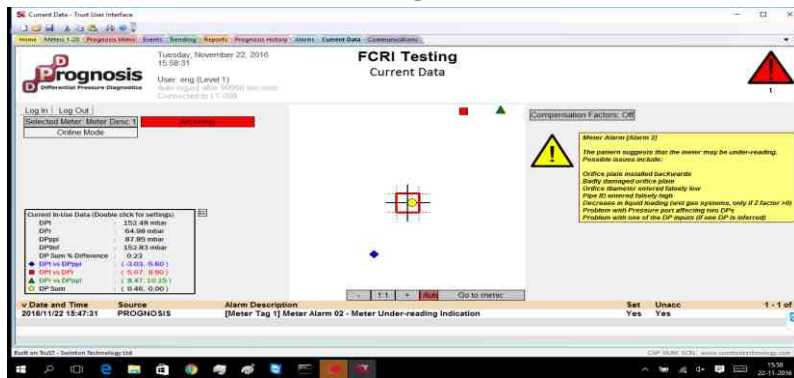


Fig. 13



**C] Results displayed on the Prognosis Screen**

Fig. 14



**D] Conclusion:**

The estimated flow rate prediction is a -17% under-reading. Prognosis can detect and guide the user to address if the orifice meter is installed backward.

**ii) Worn orifice edge**

**Objective** – Determine whether the DUT detects that the Orifice meter inserted is damaged.  
**Criteria** – DUT should react in accordance with the manufacturers' specifications.

**A] Observed Measured Readings**

Table No. 11

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter				Meter under test				Traditional Differential Pressure $\Delta P_t$ mbar	Recovery Differential Pressure $\Delta P_r$ mbar	Permanent Pressure Loss $\Delta P_{PPL}$ mbar
Pressure Pr bar a	Temperature Tr °C	Pulse Fr -	Time tr s	Actual flow rate qa m³/h	Pressure Pt bar a	Temperature Tt °C	Differential Pressure $\Delta P$ mbar			
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
16.3152	24.95	92692	60	351.41	16.1879	26.50	208.66	209.21	80.32	129.11

**B] Worn orifice plate (Id No. FE-02)**

Fig. 15

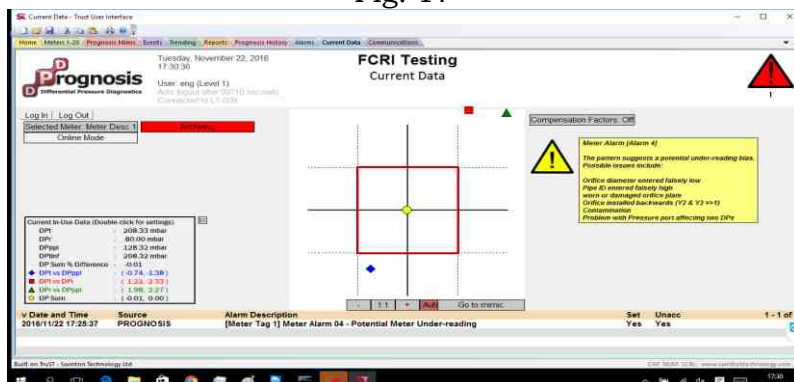


Fig. 16



**C] Results displayed on the Prognosis Screen**

Fig. 17



**D] Conclusion:**

The estimated flow rate prediction is a -3.1% under-reading. Prognosis can detect and guide the user to address if the orifice meter is damaged.

**iii) Partially blocked orifice**

**Objective** – Determine whether the DUT detects that the Orifice meter is partially blocked.  
**Criteria** – DUT should react in accordance with the manufacturers' specifications.

**A) Observed Measured Readings**

Table. 12

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter				Meter under test						
Pressure	Temperature	Pulse	Time	Actual flow rate	Pressure	Temperature	Differential Pressure	Traditional Differential Pressure	Recovery Differential Pressure	Permanent Pressure Loss
Pr	Tr	Fr	tr	qa	Pt	Tt	ΔP	ΔPt	ΔPr	ΔPPPL
bar a	°C	.	s	m <sup>3</sup> /h	bar a	°C	mbar	mbar	mbar	mbar
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
14.5529	24.26	40447	60	152.80	14.5405	26.80	98.89	100.15	22.30	78.55

**B) Partially blocked orifice (Id No. FE-03)**

Fig. 18

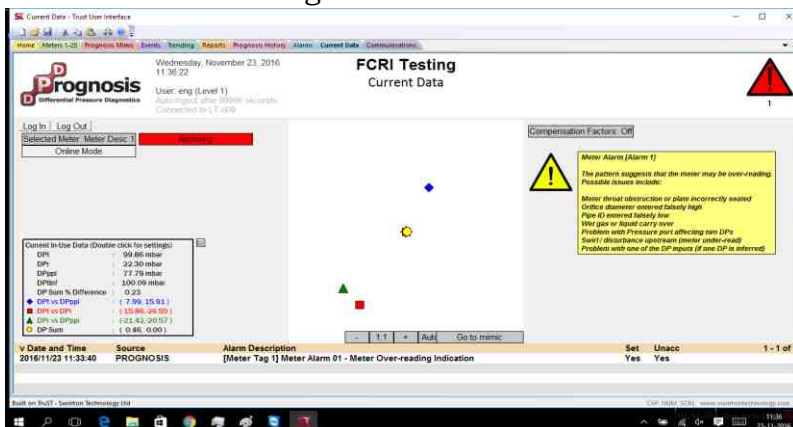


Fig. 19



**C) Results displayed on the Prognosis Screen**

Fig. 20



**D) Conclusion:**

The estimated flow rate prediction is +51% over-reading. Prognosis can detect and guide the user to address if there is any obstruction in meter throat.

**iv) Orifice installed with Smaller bore size ( $\beta = 0.5$ ).**

**Objective** – Determine whether the DUT detects that the inserted Orifice meter is of a smaller bore than expected

**Criteria** – DUT should react in accordance with the manufacturers' specifications.

- a) The plate is changed to a smaller beta by an operator but the flow computer is not updated. The calculations are based on a 0.6 beta plate but there is a 0.5 beta plate fitted in the orifice carrier.

**A) Observed Measured Readings**

Table 13

FCRI reference instruments					Orifice meter associated dp instrument values acquired through DAS					
Reference Meter				Meter under test			Traditional Differential Pressure	Recovery Differential Pressure	Permanent Pressure Loss	
Pressure	Temperature	Pulse	Time	Actual flow rate	Pressure	Temperature				Differential Pressure
Pr bar a	Tr °C	Fr -	tr s	qa m <sup>3</sup> /h	Pt bar a	Tt °C	$\Delta P$ mbar	$\Delta P_t$ mbar	$\Delta P_r$ mbar	$\Delta P_{PPL}$ mbar
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
16.2430	25.02	53418	60	201.21	16.2107	26.40	164.87	165.84	45.68	120.62

**B) Orifice with Small bore size (Id No. FE-04)**

Fig 21

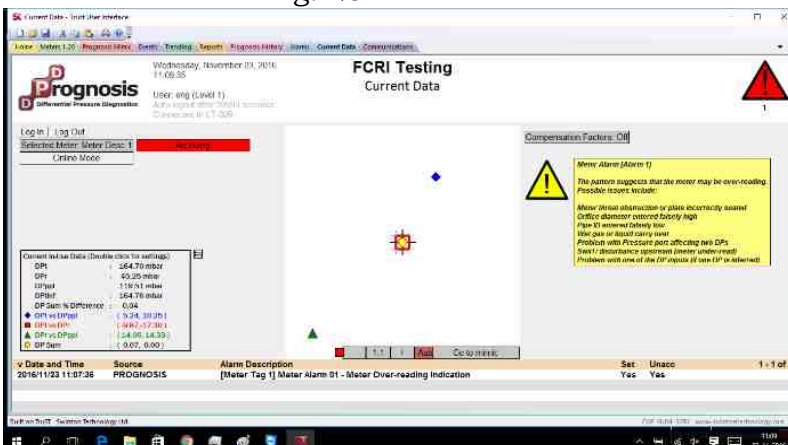


Fig 22



**C) Results displayed on the Prognosis Screen**

Fig. 23



**D) Conclusion:**

The estimated flow rate prediction is +47% over-reading. Prognosis can detect and guide the user to address if the orifice is of a smaller bore than expected.

**v) Flow straightener blocked (Upper side)**

**Objective** – Determine whether the DUT detects that there is a flow disturbance.

**Criteria** – DUT should react in accordance with the manufacturers' specifications.

**A) Observed Measured Readings**

Table 14

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter					Meter under test			Traditional Differential Pressure	Recovery Differential Pressure	Permanent Pressure Loss
Pressure	Temperature	Pulse	Time	Actual flow rate	Pressure	Temperature	Differential Pressure			
Pr bar a	Tr °C	Fr -	tr s	qa m³/h	Pt bar a	Tt °C	ΔP mbar	ΔPt mbar	ΔPr mbar	ΔPPPL mbar
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
16.4667	25.01	92392	60	354.59	16.1479	26.70	241.49	241.01	87.73	153.31

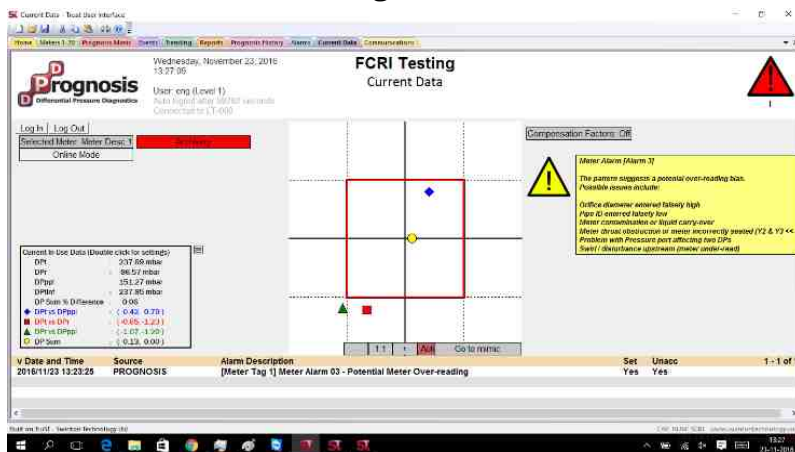
**B) Upper side blocked flow straightener**

Fig 24



**C) Results displayed on the Prognosis Screen**

Fig. 25



**D) Conclusion:**

The estimated flow rate prediction is +0.9% over-reading.

Prognosis can detect and guide the user to address if there is a swirl or disturbance upstream.

**vi) Flow straightener blocked (lower side)**

**Objective** – Determine whether the DUT detects that there is a flow disturbance.

**Criteria** – DUT should react in accordance with the manufacturers' specifications.

**A) Observed Measured Readings**

Table 15

FCRI reference instruments								Orifice meter associated dp instrument values acquired through DAS		
Reference Meter					Meter under test			Traditional Differential Pressure $\Delta Pt$ mbar	Recovery Differential Pressure $\Delta Pr$ mbar	Permanent Pressure Loss $\Delta PPPL$ mbar
Pressure Pr bar a	Temperature Tr °C	Pulse Fr -	Time tr s	Actual flow rate qa m <sup>3</sup> /h	Pressure Pt bar a	Temperature Tt °C	Differential Pressure $\Delta P$ mbar			
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
16.2960	25.07	92790	60	355.99	15.9770	26.60	240.90	240.34	87.47	153.22

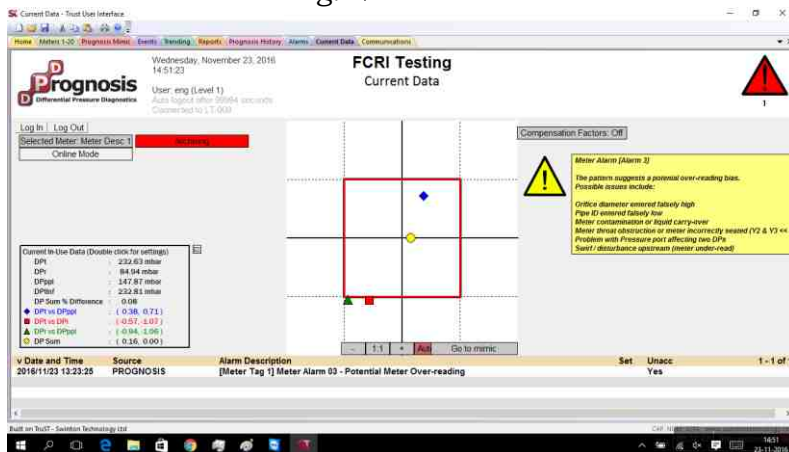
**B) Lower side blocked flow straightener**

Fig. 26



**C) Results displayed on the Prognosis Screen**

Fig. 27



**D) Conclusion:**

The estimated flow rate prediction is +0.5% over-reading. Prognosis can detect and guide the user to address if there is a swirl or disturbance in upstream.

**Conclusion Report:**

Prognosis can detect and guide the user to address the most critical issues in the Differential Pressure Meters which are mostly undetected.

Table 16

Sr.no	Test	Detection	Guided user to address	Pass	Result
<b>TEST A</b>					
1	Input the meter inlet diameter to flow computer too high	Yes	Yes	√	Prognosis can detect and guide user to address if the in use inlet diameter of orifice is high.
2	Input the meter inlet diameter to flow computer too low	Yes	Yes	√	Prognosis can detect and guide user to address if the in use inlet diameter of orifice is low.
3	Input the meter orifice diameter to flow computer too high	Yes	Yes	√	Prognosis can detect and guide user to address if the in use orifice diameter is high.
4	Input the meter orifice diameter to flow computer too low	Yes	Yes	√	Prognosis can detect and guide user to address if the in use orifice diameter is low.
5	Faulty DP reading (e.g., drifting transmitter, scaling error or badly calibrated transmitter)	Yes	Yes	√	Prognosis can detect and guide user to address if there is an error in DP reading cause by (for example) incorrect scaling, faulty, drifting or badly calibrated transmitter.
6	Faulty DP readings (Leaking Manifold)	Yes	Yes	√	Prognosis can detect and guide the user to address if there is an error in DP reading cause by (for example) a leaking manifold or equalization valve not fully closed.
<b>TEST B</b>					
7	Orifice plate installed backward	Yes	Yes	√	Prognosis can detect and guide the user to address if the orifice is installed backward.
8	Worn orifice edge	Yes	Yes	√	Prognosis can detect and guide the user to address if the orifice meter is damaged.
9	Partially blocked orifice	Yes	Yes	√	Prognosis can detect and guide the user to address if there is any obstruction in meter throat.
10	Orifice installed with smaller bore size ( $\beta = 0.5$ )	Yes	Yes	√	Prognosis can detect and guide the user to address if the orifice meter is of a smaller bore than expected.
11	Flow Straightener Blocked				
11.1	Flow straightener blocked (Upper Side)	Yes	Yes	√	Prognosis can detect and guide the user to address if there is a swirl or disturbance upstream.
11.2	Flow straightener blocked (Lower Side)	Yes	Yes	√	Prognosis can detect and guide the user to address if there is a swirl or disturbance upstream.